THE GEOLOGY OF PETE'S CANYON AREA, SAN PETE COUNTY, UTAH

Submitted by Dale M. Lewis

Geology 570

Winter Quarter 1970

LOCATION

The area covered in this report is located in central Utah, San Pete County, approximately 125-150 miles south of Salt Lake City near the small village of Wales. The area mapped is approximately ten square miles and comprises Salt Lake Meridian T15S, R2E, sections 33-36 and T16S, R2E sections 1-4 and parts of T15S, R3E, section 31 and T16S, R3E, section 6.

GEOGRAPHY

The entire region is sparsely populated and this particular area contains only a few agricultural buildings and fences. Access to the area is limited to a county road along the front boundary in Sanpete Valley and a very unimproved road four miles west along the back boundary on the Gunnison Plateau.

The climate is semi-arid, with about 12 inches of rain a year, and varies only slightly from the valley floor to the plateau top. Characteristic plants include juniper, cactus, oak brush, cottonwoods (around streams and springs) and sage.

The topography is dominated by the broad plateau of the Gunnison, the mature Sanpete Valley and the steep canyons cut in the plateau. The combination of these features has produced an area with very steep slopes separating the Gunnison Plateau from the canyon floors and Sanpete Valley.

PRESENT WORK

The area is under continued study each field season through the summer field program sponsored by the Geology Department at the Ohio State University. Most recently the area was mapped on a reconnaissance basis by a three man party of which the writer was a member.

PREVIOUS WORK

The Pete's Canyon area has received cursory and some detailed study in relation to regional relationships. The most significant work has been done by E. M. Spieker (1925; 1946; 1949), C. T. Hardy (1952), Armstrong (1968) and other graduate students at the Ohio State University and other universities.

ACKNOWLEDGEMENT

Gratitude is extended to the other members of the field party, Robert Arter and Jerry Derbyshire, whose field work and discussion have contributed substantially to this report. Further thanks is expressed to the faculty represented at the field camp, especially Richard Threet, Charles H. Shultz and James W. Collinson, whose instruction and discussion made the study a success.

STRATIGRAPHY

Jurassic

Twist Gulch Formation

Definition

E. M. Spieker originally defined the Twist Gulch formation as a member of the Arapien shale along with the Twelve Mile Canyon member. As such it comprises the strata exposed on the north side of Salina Canyon above Twist Gulch and lies between the compact red salt-bearing shale of Twist Gulch and the diverse strata of the Morrison (?) formation (Spieker 1946, p.124). Subsequent work has raised the Twist Gulch and Twelve Mile Canyon members to formational status (Hardy 1952) and Arapien is now the group name or is interchanged with the Twelve Mile Canyon member. In the studied area the formation was distinguished on the basis of lithology.

Description

The Twist Gulch formation contains several sedimentary features which indicate that the deposit had a fluvial origin. This is also confirmed by the stratigraphic relationships which indicate a transition from marine (underlying Twelve Mile Canyon member evaporites) to definite continental (overlying Morrison (?) conglomerate). Sedimentary structures include crossbedding, lensing, soft sediment deformation, and a general lack of sorting. Graded bedding is observed in places in massive beds. The crossbedding is not always well developed but it can be relied upon for determination of top and bottom. This was especially important since no marker bed was found that would delineate the complex structure. In fact, the faults which affect the Jurassic rocks were first located by finding reversals in bed orientation as indicated by crossbedding.

The composition of the formation is very consistent in the area studied and according to other reports the lithology is similar throughout central Utah (Spieker, 1946; Hardy, 1952). Generally it consists of interbedded red beds of mudstone, siltstone and sandstone. The grain size ranges from clay to coarse sand but the average size is fine sand. The dominant lithology is an argillaceus sandstone randomly interbedded with mudstone, siltstone and coarse sandstone. One of the most striking characteristics of the Twist Gulch is its color which varies from dark reddish brown to red. Although most of the formation is red, there are many thin beds of white sandstone but these do not subdue the brilliance of the Twist Gulch.

The major mineral is well-rounded, milky quartz which is cemented by hematite and a very small amount of calcite. Additional minerals found as grains are red quartz, clay and feldspar of undetermined composition. Some massive beds contain enough feldspar (average size $\sim$2mm) to warrant the name arkose. Such minor minerals suggest a minor concentration of igneous rocks in the source area.

Weathering of the Twist Gulch has produced two common phenomena which are inherent in the lithologies affected. The surfaces of some siltstones and sandstones are not red but green, indicating reduction of the iron in hematite to another iron bearing mineral. Weathering of the muddy siltstones produces blocky fragments indicative of their clay content. This particular type of bed is also the most susceptible to weathering and small tributaries to the main streams often develop along the strike of these soft strata.

Distribution and Thickness

The Twist Gulch formation is exposed in several places in Sanpete Valley, Sevier Valley and on the west side of the Gunnison Plateau. It occurs in a belt along the east front of the Gunnison Plateau from near Wales, Utah to Gunnison, Utah. The most complete section of Twist Gulch is in Salina Canyon where 3,000 feet of section have been measured (Spieker, 1946). Additional outcrops occur mear Indianola but deformation precludes accurate measurement. On the west side of the Gunnison Plateau near Levan, Hardy and Zeller report a thickness of 1,839 feet (Hardy and Zeller, 1953).

The thickness of the Twist Gulch was impossible to measure accurately in the Pete's Canyon area since the section measured included three faults with the beds overturned on one fault block. The section extends from where the beds emerge from under the Sanpete Valley alluvium to the thrust contact with the Morrison (?) formation. The total thickness obtained was 1,020 feet and if faulting were removed the minimum thickness could be no less than 500 feet. The structural involvement of the Twist Gulch has impeded the establishment of isopachs and led Spieker to emphasize that his measured section was valid only in Salina Canyon (Spieker, 1946).

Stratigraphic Relations

The stratigraphic relations of the Twist Gulch could not be worked out in the area studied but they are evident elsewhere in central Utah. Spieker has shown that the Twist Gulch conformably overlies the Twelve Mile formation and is gradational with it. Similarly, it is overlain in apparent conformable relations by the Morrison (?) formation at Salina Canyon (Spieker, 1946) and at one location in section 36, T15S, R16E of the study area. This boundary is definitely gradational. The Twist Gulch formation is overlain unconformably by the Flagstaff limestone in Salina Canyon and by the Price River Formation and North Horn Formation in the Gunnison Plateau.

Age and Correlation

No fossils have been found in the Twist Gulch formation but Spieker's unit 2 of the Twelve Mile member contains fossils of Upper Jurassic age (Spieker, 1946). Owing to its conformable relationships the Twist Gulch is assumed to be Upper Jurassic. According to Hardy the Twist Gulch is probably at least the lithologic equivalent of the Entrada, Curtis, and Summerville formations of the San Rafael group (Hardy, 1952, p. 27-28).

Morrison (?) Formation

Definition

The Morrison (?) formation was originally defined by E. M. Spieker because it occupies the stratigraphic position and had the attributes of the Morrison formation, but it can not be directly correlated with it. The Morrison formation is widely recognized in the Colorado Plateau and isopachs showing its westward thinning indicate that its boundary would fall to the west of Sanpete Valley (Spieker, 1946, p. 146). In the area studied the Morrison(?) was identified on the basis of lithology which was not consistent with Twist Gulch and the similarity to other outcrops known to be Morrison(?). There is some doubt as to whether the rocks in this area should be called Morrison(?) or Indianola undifferentiated. The latter seems to be favored by some (Spieker, 1946) and the former by others (Hardy, 1952) including the writer. However, the specific name attached to it is not especially important if the structural and stratigraphic relations are known.

Description

The Morrison (?) formation consists of a conglomerate at the base and grades upward into a bright orange-red, fine grained sandstone and coarse white sandstone. The base of the measured section is on the arm-like spur south of Pete's Canyon in the SE 1/4, sec 1, T 16 S, R2E. The Morrison (?) is a fluvial, piedmont deposit of siltstone, sandstone, and conglomerate. Much of the formation in this area is a white, slightly calcareous, medium to coarse grained, well rounded sandstone which is interbedded with a red to pink, medium to fine grained sandstone with calcareous and hematite cement. On a thrust plate in the N 1/4, SW 1/4, sec 36, T 15 S, R16E; and in North Coal Canyon there is a prominent reddish-orange, very fine grained sandstone with exceptional examples of oscillation ripple marks. The top of the formation can not be found because thrust faulting truncates the formation. Although the deformation precludes finding an exposure of the entire section at one location the succession of beds is as follows: conglomerate, white sandstone interbedded with red sandstone, red-orange sandstone.

The conglomerate is reddish purple and contains pebbles of quartzite and limestone. The interstices between the pebbles are filled with a matrix of quartz grains and lithic fragments from coarse to fine in size. The predominate mineral of the white sandstone is milky quartz with some red and yellow quartz and small amounts of muscovite and biotite. The red-orange sandstone is mostly fine grained quartz with hematite cement.

Sedimentary structures include ripple marks and cross-bedding. The conglomerate contains the fewest structures but occasionally thin interbeds and lenses of sandstone contain crossbedding of the quality necessary to determine tops and bottoms of beds. The dominate structure in the white sandstone is crossbedding which is of good quality and contains foreset beds up to one foot in thickness. The red-orange beds include excellent oscillation ripple marks in addition to good crossbedding. All these features were used only to determine tops and bottoms of beds. It would probably be possible to collect enough data from these beds and the underlying Twist Gulch to confirm the dispersal pattern during the late Jurassic.

Distribution and Thickness

The Morrison (?) formation is found near Thistle, near Salina, (Spieker, 1946) and along the east front of the Gunnison Plateau in Sanpete Valley. In all likelihood, the Morrison (?) and the Indianola undifferentiated are undistinguishable in some places and the distribution of the latter should also be mentioned. In addition to the aforementioned places, the Indianola undifferentiated outcrops in the Cedar Hills, along the east side of the Gunnison Plateau, (Spieker, 1946) and along the west side of the Gunnison (Hardy, 1952).

The thickness of the Morrison (?) formation seems to be anamolously great if it is in fact a westward extension of the Morrison formation of the Colorado Plateaus. Near Salina 1,300 feet of section were measured and near Thistle estimations of approximately 1,800 feet have been made (Spieker, 1946). In the Pete's Canyon area the author and his associates measured 520 feet of section but this is certainly incomplete due to thrusting and an angular unconformity.

Stratigraphic Relations

The Morrison (?) formation is underlain conformably by the Twist Gulch formation and wherever observed this contact is gradational. The formation is overlain by the Indianola group and this contact is similarly conformable and gradational. The Morrison (?) is overlain unconformably by the North Horn formation and Flagstaff limestone in several areas; most notably in Salina Canyon and in the Gunnison Plateau west of Mayfield.

Age and Correlation

The age of the Morrison (?) can be only grossly placed since both it and the underlying Twist Gulch do not contain fossils. It is, however, either late Jurassic or Cretaceous. The most creditable estimate makes it Upper Jurassic (Spieker 1946) but even this designation is tenuous and not to be accepted dogmatically.

The Morrison (?) has been tenatively correlated with the Morrison formation of the Colorado Plateaus based on its stratigraphic position and lithologic similarity to the latter formation. As stated above, the thicknesses do not seem to be compatible and there is a lack of fossil record both of which dispute such a correlation (Spieker, 1946).

Cretaceous - Tertiary

North Horn Formation

Definition

The North Horn formation was originally defined as the lower member of the Wasatch formation of the Wasatch Plateau and southern Utah (Spieker and Reeside, 1925). Further work and thought led Spieker to redefine the North Horn as a formation which lies stratigraphically below the Wasatch formation equivalents in the Wasatch Plateau. At the type section on North Horn Mountain the formation is divided into four easily traceable units of alternating flood plain and lacustrine origin. The fourfold division gradually disappears away from the area centered around Manti and local divisions take their place, (Spieker, 1946).

In the Pete's Canyon area the North Horn was divided into three easily recognizable members. In ascending order these are the Red Member, the North Coal Canyon Member, and the Pete's Canyon Member. The Price River formation was not differentiated in this area because outcrops of known Price River were small. In any case, the Red Member includes at its base a thick section of conglomerate which would be called the Price River formation. Along with these conglomerates the Red Member also contains 300 feet of siltstone so the Red Member can not be simply relabelled as the Price River formation. Such non naming of the Price River in Pete's Canyon area does not affect the geologic interpretations. To the east, south, and north the Price River is in conformable, gradational contact with the North Horn. To the west some angular unconformability does exist and this will be considered later (see Geologic History).

Description

The North Horn is a thick formation of fluvial and lacustrine origin. Its progression of sediments from pebble conglomerate, to fine grained clastics, to interbedded clastics and lacustrine limestone records the transition from a near mountain source to a flood plain and lacustrine environment in front of eroded mountains. To a large degree the three members are indicative of the environment of deposition.

The Red Member records the coarse clastic stage of post orogenic erosion, the North Coal Canyon Member records a transitory period when the lake first started to encroach on the area, and the Pete's Canyon Member records the alternation of floodplain and lacustrine environments.

The basal beds of the Red Member are a pebble and cobble conglomerate with quartzite, limestone, and sandstone as pebbles and cobbles, and calcite and coarse sand as matrix. This conglomerate is generally a deep red color although some white conglomerate beds are found. Where this conglomerate is in close proximity with the Morrison (?) conglomerate care must be exercised to avoid misinterpretation of the structure and stratigraphy. Above the conglomerate there is approximately 300 feet of red and greenish-gray arenaceous siltstone which is quite extensive. In places, especially in North Coal Canyon, these arenaceous siltstones weather to form badlands topography and "ball bearing" slopes. These arenaceous siltstones as well as the matrix of the conglomerate are so similar to the Twist Gulch and Morrison (?) formations in lithology that one must assume that the source of these beds, at least in part, was the underlying, older formations.

The North Coal Canyon Member consists of siltstone, sandstone, limestone and carbonaceous beds. The unit begins at the top of the red and greenish-gray siltstones previously described and is approximately 300 feet thick. The base of the unit is mostly arenaceous gray siltstone with several massive (3-6 feet thick) beds of medium to coarse grained sandstone. These sandstone beds contain good crossbedding and flute casts on the top of some beds. The top of this member consists of a prominent coal seam 4 to 5 feet thick. The unit resembles a classic cyclothem but there is no overlying marine sequence, only one coal seam underlain by 30-40 feet of related sedimentary rocks of a shallow water, reducing environment. The coal seam is overlain by a massive gray limestone, the bottom of which is the boundary between the North Coal Canyon and Pete's Canyon Members.

The base of the Pete's Canyon Member is the distinctive massive gray limestone referred to above. Above this bed there are several limestones interspersed throughout a section dominated by purple to brown mudstone. Although mudstone dominates the section, there are numerous interbeds of limestone and sandstone. The limestones, which are commonly arenaceous and argillaceous, and the sandstones form small ledges on the otherwise smooth debris strewn surface of the weathered slopes. Near the top of the unit the ratio of limestone beds to sandstone beds is 5:1 but mudstone is still the dominate lithology. At the top of this unit there is a set of ~~these~~ red siltstones with some medium beds of limestone. Above these beds are the cliff forming limestones of the lower Flagstaff. This set of beds is distinctive and can be traced along the entire east front of the Gunnison Plateau. It is especially useful in observing the relationship between the North Horn and the Flagstaff formations. In Pete's Canyon NE 1/4, sec 3, T 16 S, R2E there is a good example of interfingering of this member and the Flagstaff.

Distribution and Thickness

As originally defined, the four units of the North Horn can be traced in a 600 square mile area whose center is east of Manti. Outside of this area the fourfold division disappears but the North Horn formation can be traced (Spieker, 1946). It is found throughout the Wasatch Plateau and is the dominate formation in most of the Gunnison Plateau. The formation thins southwestward from 2,500 feet between Castlegate and Soldier Summit to 500 feet on Salina Creek (Hunt, 1956). A local thinning can be observed in the Gunnison Plateau from 2,900 feet near Wales to approximately 500 feet near Gunnison. This is a result of overlap on the Jurassic rocks which remained positive during part of the deposition of the North Horn.

Stratigraphic Relations

The North Horn formation is conformable and gradational with the Price River formation of the Wasatch Plateau and most of the Gunnison Plateau. On the west side of the

Gunnison Plateau an angular nonconformity between the Price River and North Horn has been observed (Hardy and Zeller, 1953). The formation is conformable with the overlying Flagstaff limestone except for one location in the Wasatch Plateau at Sixmile Canyon (Spieker, 1946). Elsewhere the contact is not only conformable and gradational but demonstrates intertonguing (see Description; Pete's Canyon Member).

The lateral stratigraphic relationship of the North Horn formation of the Gunnison Plateau vary in a reasonable but profound manner. The formation displays a great facies change within a distance of ten miles along the east side of the plateau. Two miles south of North Coal Canyon where the section was measured, the siltstones change to sand-stones which intertongue with conglomerate. Still further south, in the vicinity of South Coal Canyon, the sandstone section changes to thick units of conglomerate.

Age and Correlation

In the Wasatch Plateau the lower part of the North Horn formation is uppermost Cretaceous as based on dinosaourian remains and the upper part is Paleocene as based on mammalian remains (Gazin, 1938; Spieker, 1946). A similar age is assumed for the North Horn formation in the Gunnison Plateau since the distance separating the fossil location and the plateau is not too great and the stratigraphy is straight forward. It is likely that the time boundary is higher in the Gunnison Plateau section than in the Wasatch Plateau.

The formation has been correlated in part with the Lance and Fort Union formations of the northern plains and with the Ojo Alamo, Puerco, and Torrejon formations of the San Juan Basin. These correlations are based on time equivalence and not continuation of lithic character (Spieker, 1946). The Canyon Range fanglomerate might be the western terminus of the North Horn but the correlation is not proven and is questioned by some (Armstrong, 1968).

Tertiary

Flagstaff Limestone

Definition

The Flagstaff limestone was originally defined as the middle member of the Wasatch formation (Spieker and Reeside, 1925). Subsequently the Flagstaff has been redefined as a formation even though its stratigraphic limits were not (Spieker, 1946). In the area studied the Flagstaff limestone consists of a lower cliff forming member and an upper slope forming member. The base of the formation is arbitrarily located at the top of the first red bed below the cliff forming limestones and the upper limit is at the base of the first red siltstone above the massive limestone. Other workers in the region have used a thin fossiliferous limestone as the upper limit, but it is often covered and is not as easy to locate as the above contact. This bed is approximately 250 feet down section from the contact used in this report.

Description

The Flagstaff limestone was unimaginatively divided into the Upper Flagstaff member and the Lower Flagstaff member. The Lower Flagstaff forms the very prominent cliffs which rim the Gunnison Plateau while the Upper Flagstaff forms the subdued slopes above the cliffs.

The Lower Flagstaff member is lacustrine in origin, being composed almost exclusively of arenaceous limestone and occasional very sandy beds. The color of the rock is light yellow to yellow brown both on the fresh and weathered surfaces. The limestone is in massive weather resistant beds which form cliffs 200 - 300 feet high. The unit weathers along vertical joints to form elongate, upright spires. The major weathering product, however, is subangular rock fragments of 1/2 to several inches in diameter, which cover the slope below the cliffs and produce the deceiving and treacherous "ball bearing" slopes.

The base of the Upper Flagstaff is a variegated, arenaceous limestone which weathers brownish yellow and is a weak ledge former. The contact between the upper and lower members is at the top of the cliff forming limestones.

Massive beds of yellow-brown mudstone are included in the member and weathering of these produces covered slopes in large portions of the region. A small part of the member is quartzitic, calcareous, limonitic sandstone. Limestone comprises a large portion of the unit but it usually contains impurities of sand, silt, and clay (both as a grain size and as minerals), and is often interbedded with shale and mudstone. One extremely fossiliferous dark gray limestone bed is so distinctive that it might be used as a key horizon in stratigraphic work. The bed varies in thickness from six to eighteen inches and is often covered by debris on the slopes. At the top of the unit is a 57 foot interval of interbedded green mudstones and calcareous sandstone. Contained within this interval is a thin white argillaceous limestone with gray to black chert nodules.

Distribution and Thickness

The Flagstaff limestone is present everywhere in the Wasatch and Gunnison Plateaus. Its eastward limit lies approximately 30 miles to the east in the Book Cliffs. The formation has a tongue-like shape and extends westward and southwestward from the Thistle area for a radial distance of over 75 miles (Spieker, 1946; Hunt, 1956). The thickness ranges between 200 - 1500 feet and averages between 800 - 1000 feet. It thickens to the west and southwest. The thickness in North Coal Canyon was 815 feet.

Stratigraphic Relations

The contact of the Flagstaff limestone with the underlying North Horn formation is conformable and gradational except for the Sixmile Canyon area and other local areas where the North Horn is not present. In the Gunnison Plateau the Flagstaff is extremely gradational with the Colton formation, and a similar relationship is known in the Wasatch Plateau. East of the Wasatch Plateau the Flagstaff intertongues with and grades into the variegated beds of the Colton formation (Hunt, 1956). In the southern part of the High Plateaus the Flagstaff and its equivalent overlap all of the Cretaceous and Jurassic formations where they have been sharply folded (Spieker, 1946).

Age and Correlation

The Flagstaff limestone has been correlated with the Wasatch formation of southern Utah (Hunt, 1956). A very tentative correlation states that the Canyon Range fanglomerate may be the western extent of the Flagstaff limestone (Armstrong, 1968). The age of the Flagstaff is upper Paleocene and/or Eocene (?) based upon molluscan fauna examined by La Rocque (1951).

Colton Formation

Definition

The rocks of the Colton formation were originally defined as the upper member of the Wasatch but they have been redefined as a separate formation (Spieker, 1946). The formation at the type section consists of the beds in the hills north of Colton between the Flagstaff limestone and the Green River Formation. The base of the Colton in the area studied is the first red mudstone encountered in a series of siltstones and mudstones previously described as uppermost Flagstaff. The upper limit of the Colton is at the top of the last prominent red bed in the section.

Description

The Colton is probably a combination of fluvial and lacustrine sedimentary rocks and may represent fluctuations between the Flagstaff lake and the lake of Green River time. The Colton has a red arenaceous mudstone at the base and this type of lithology composes 25% of the formation. Another large percentage is gray-green mudstone which differs from the red mudstone only in color. Near the top of the section there are more siltstones than mudstone.

Sandstone is found throughout the section and has the same general composition where ever present. The sandstones vary from fine to medium grained and are composed of quartz with some muscovite and biotite. The sandstones are characteristically green and it is inferred that this is due to some clay mineral. One sandstone is of particular interest because it represents a stream during Colton time. The unit, which is of varying thickness (5 - 30 feet), contains much crossbedding. The deposit is not present everywhere and it is this fact which makes one assume it is the deposit of a wandering stream.

An appreciable percentage (5 - 10%) of the formation is composed of limestone that is extremely fine grained, sometimes recrystallized, and not very fossiliferous.

Distribution and Thickness

The Colton formation is extensively exposed in the Tavaputs Plateau to the east of the type section. On the Wasatch Plateau there are some variegated beds in Joe's Valley graben which may be Colton. On the west flank of the Wasatch Plateau it is present at the base of the monocline at many localities between Salina and Mount Pleasant. It is found locally on the Gunnison Plateau where it intertongues with the Flagstaff and Green River (Spieker, 1946).

The maximum thickness of the Colton is nearly 2000 feet along Green River. It thins westward by intertonguing with the Flagstaff limestone and Green River formations (Hunt, 1956). Above Kyune at the head of Price Canyon the formation is 1500 feet thick (Spieker, 1946). In the area studied a complete section of Colton was present between the Upper Flagstaff and Green River formation and measured 740 feet in thickness.

Stratigraphic Relations

The contacts of the Colton are extremely gradational with the Flagstaff limestone and the Green River formations.

The only distinction that can be made at a contact is color and even this is a gradational characteristic. The Colton tongues into the Flagstaff and Green River formation so much that it thins westward from the type section. In fact Spieker (1946) thinks that the entire Colton formation is chronologically equivalent to part of the Green River formation due to intertonguing. Eastward, the upper part of the Colton intertongues with, and grades laterally into the Green River formation. The Colton is in conformable contact with the underlying beds except in the Salina Canyon area where it overlaps folded Jurassic formations.

Age and Correlation

The Colton formation may be correlative in part with beds referred to as Wasatch in the eastern and northern parts of the Uinta Basin (Hunt, 1956). The only fossils found in the Colton are not very diagnostic. No vertebrate fossils have been found and the few mollusks that have been found are not sufficient proof to show that the Colton is or is not of Wasatch age (Spieker, 1946). The intertonguing of the Colton and Green River formations makes them time equivalent.

Green River Formation

Definition

The Green River was defined as a formation by Hayden (1869) when he encountered an undescribed group of rocks near Rock Spring Station, Wyoming. Subsequently, section descriptions of Green River formation typical of central Utah have been published (Spieker, 1946). In the area studied only a partial section of Green River is present since Quaternary erosion has removed much of it. As described above the lower contact with the Colton formation is gradational but is placed at the last prominent red bed in the series of fluviatile fine clastics. Generally, the Green River can be easily designated by its distinct lithology of green and gray siltstones.

Description

The Green River, by definition, contains no red beds in the area studied. The basal beds of the Green River are gray green, calcareous, arenaceous siltstone which is the dominant lithology in this area. Included in the Green River are sandstone beds of quartz with calcareous cement. About 30% of the formation is composed of limestone which varies from rather pure limestone through argillaceous and arenaceous to dolomitic limestone. The stratigraphic position of these can be seen in the columnar section. In general, the Green River formation is composed of calcareous mudstone and siltstone, limestone and a small percentage of sandstone.

Distribution and Thickness

The Green River formation underlies the Uinta Basin and extends northward into the Wyoming Basin. The southern limit of the formation is probably the epeirogenic platform of the Colorado Plateau (Hunt, 1956). The Green River lies at the base of the Wasatch monocline where it forms numerous cuestas. It is found in the Gunnison Plateau capping the highest peaks. In the area studied 195 feet of section is all that has survived erosion of the uplifted plateau.

Stratigraphic Relations

The Green River formation conformably overlies the Colton formation and is gradational with it. It represents the encroachment of a large lake into the areas where the Colton was being deposited. It intertongues with the Colton to a considerable degree as described above (Hunt, 1956). In spite of the intertonguing with the Colton formation, the Green River is very consistent in lateral composition.

Age

The Green River formation is middle Eocene in age near the type section in the Colorado Plateaus. Owing to the pronounced intertonguing the rocks of the Gunnison Plateau are not the exact same age as those at the type section. However, the time difference is probably quite small and the Eocene age is accepted for this report.

STRUCTURAL GEOLOGY

Regional Structure

The area studied lies in the transition zone between the Basin and Range Province and the High Plateaus division of the Colorado Plateau Province. It is therefore necessary to consider some of the pronounced regional structures of both provinces in an attempt to relate the local structure to a broader view of the geologic history.

The High Plateaus are characterized by particular types of folding and faulting. The predominant type of fold is the monocline of which the Wasatch Monocline is a classic example. This monocline forms the west flank of the Wasatch Plateau and extends in a northeast direction for more than 30 miles. This monocline is often considered the western boundary of the Colorado Plateau but some workers have reported a more subdued monocline on the west side of the Gunnison Plateau (Hardy and Zeller, 1953).

The late Mesozoic and Tertiary rocks of the Gunnison Plateau, however, are not strongly folded and this monocline is not dominant. The top of the Plateau is a syncline which is of low dip and plunges to the south (Gilliland, 1963). The Gunnison syncline is 15 miles wide and approximately 40 miles long.

A major structure in central Utah is the Sanpete-Sevier Valley anticline which underlies the two valleys for which it is named. The folded rocks range in age from Jurassic to Cretaceous but the youngest rocks folded are the Indianola group. The fold trends northwest and plunges in the same direction. The amount of plunge between Sterling and Moroni is 15,000 feet. The anticline is 65 - 70 miles long and has an estimated structural relief of 13,000 - 15,000 feet (Gilliland, 1963).

Associated with this anticline is the Redmond Hills anticline which is smaller and less known (Gilliland, 1963).

The faulting in the region is of three types: thrust, normal, and horst and graben faults. The horst and graben faulting is characteristic of the High Plateaus to the east of the area studied. Joe's Valley Graben is a typical example of this late Tertiary faulting which involves beds as young as the Colton formation. To the west, the normal faults of the Basin and Range Province dominate the structure (Armstrong, 1968). Related faults in central Utah include the east Gunnison fault and the fault along the west side of the Gunnison Plateau. The east Gunnison fault has a displacement of nearly 8,000 feet north of Ephraim but this decreases southward toward Gunnison, Utah where the displacement is negligible (Gilliland, 1963). These faults are late Tertiary and affect all the formations in central Utah.

Recent work has shown that the dominant pre-Montana age structure of the eastern Great Basin was thrust faulting. In the Wah Wah-Canyon Range district eocambrian and Lower Cambrian rocks have been thrusted eastward over Lower Cambrian to Jurassic rocks. The major thrust fault is locally called the Wah Wah thrust, Frisco thrust, Mineral Range thrust, Pavant thrust, and the Canyon Range thrust (Armstrong, 1968).

At the base of the Wasatch, Price River, North Horn and older Tertiary formations there is an angular unconformity in the Colorado Plateau and the transition zone between the two major provinces. This unconformity has been studied at four places in the Colorado Plateau:

1) the south flank of the San Juan Mountains
2) west flank of the Circle Cliffs upwarp
3) the northeast flank of the upwarp at the head of the Fremont River
4) the west side of the Wasatch Plateau (Hunt, 1956)

This unconformity has been described in central Utah by E. M. Spieker (1946, 1949) and others, most notably Hardy (1952, 1953) and Gilliland (1963).

Local Structure

Folds

The only exposure of Jurassic rocks which has not been affected by the local thrust faulting lies unconformably below the Red Member of the North Horn formation in the SE 1/4, NW 1/2, Sec.36, R2E, T15S. At this one locality the Morrison (?) formation is overturned, strikes N15W and dips 58° E. From this orientation it is evident that the formation lies on the west limb of an anticline whose axial plane lies to the east in Sanpete Valley. These rocks lie in an orientation that is on strike with similar rocks unconformably below the North Horn conglomerate at Point of the Mountain a few miles south. Gilliland has delineated the size, shape, and orientation of a large anticline in Sanpete Valley which involves Twelve Mile Canyon formation (Arapien), Twist Gulch formation and the Indianola group (Gilliland, 1963). It is therefore suggested that these beds of Morrison (?) are part of the west limb of this overturned, asymmetrical anticline.

Above the angular unconformity the North Horn and younger formations dip gently to the west. The dips of these beds are greatest near the base of the North Horn and near the front of the Plateau. For example, in North Coal Canyon, Pete's Canyon and the small canyons in between the two, the North Horn strikes N10°W to N30°W and dips 17°W to 21°W. At the base of the Flagstaff in the heads of these same canyons the strikes are unchanged but the dips are reduced to 10°W to 7°W. Similarly, at the western boundary of the area mapped the strike of the Colton and Green River formations is N20°W - N25°W and the dip is 4°W to 2°W. This decrease in dip is systematic away from the front of the

Gunnison Plateau and is best described a synclinal flexure. On the west edge of the Gunnison Plateau these same formations dip gently east. It is quite clear that the synclinal flexure of the studied area is on the east limb of the south plunging Gunnison syncline described by Gilliland (1963).

The only other folding that occurs is too small to be mapped and is related to the local thrusting of the Twist Gulch formation. One excellent example of this small scale folding occurred on the Morrison (?) thrust sheet in the N 1/2, SW 1/4, Sec.36, R2E, T15S. The conglomerate and sandstone of the thrusted Morrison (?) form an antiform whose axial plane strikes N20°W and dips 30°SW. The folding could have occurred in one of two ways. It may have formed contemporaneously with the thrust faulting as a result of friction and compression. An alternate possibility is that the rocks were thrust into a position structurally higher than their present position without significant folding. Subsequently, movement in the opposite direction on the thrust plane may have produced forces which caused the rocks to fold in camber fashion. Of the two possibilities the former seems more acceptable in the light of the facts that the surrounding, more incompetent Twist Gulch is not affected greatly by folding. This could occur if the thrusts occurred at slightly different times allowing the Morrison (?) to fold while the Twist Gulch was not folded.

Other minor folds include nearly vertical beds of North Horn sandstone on the north side of Pete's Canyon near the canyon mouth. The orientations are chaotic and no one fold can be traced very far. This deformation is very limited as the dips of the North Horn formation return to normal within a few tens of feet along the north wall of Pete's Canyon. It is assumed that this irregular folding is the result of thrust sheets overriding the base of the North Horn formation.

Faults

The most prevalent faults are high angle thrust faults of Twist Gulch and Morrison (?) formations over the North Horn formation. Four such faults were located along the base of the Gunnison Plateau. The oldest thrust includes Twist Gulch formation which is overturned and dips 46°E to 50°E. The fault plane dips somewhat less than this and is also to the east. It is clear that this plate was thrust upon the North Horn formation. The truncated beds of the North Horn under Twist Gulch can be seen in the bottom of a small canyon in the N 1/2, SW 1/4, Sec. 36, R2E, T15S.

The other three thrust plates have been thrust upon the first in an imbricant fashion. It can be seen that these plates overrode one another as they were emplaced. The second thrust east from the base of the North Horn formation is entirely Morrison (?) formation which is overturned and dips 40^{o}E to 60^{o}E depending on the location in the thrust plate. In North Coal Canyon this thrust plate is in direct contact with the North Horn formation and has completely overridden the first thrust plate.

The third thrust plate east of the mountain base contains Twist Gulch formation which is overturned and dips 40^{o}E to 50^{o}E. This thrust can be traced for one and a quarter miles from North Coal Canyon to a point in Sec. 1, R2E, T16S where it goes under the valley alluvium. In one location shortly before the thrust contact swings into the valley alluvium it has completely overridden the second thrust (Morrison (?)) and overlaps the first thrust (NE 1/4, NW 1/4, Sec. 1, R2E, T16S).

The fourth thrust contains Twist Gulch formation which is right side up and dips 35^{o}E to 60^{o}E depending on where the dip is measured. It was located by finding a reversal in the orientation of the beds in regard to the tops of beds. Its relationship is not as clear cut as some of the other thrusts because all the thrust contacts merge or come close to merging in the small canyon in the S 1/2, NW 1/4, Sec. 36, R2E, T15S. From relationships observed in North Coal Canyon it appears that this thrust overrides the third thrust and lies on the Morrison (?) thrust. This thrust also cannot be traced completely along the front of the Gunnison as it goes under the valley alluvium just north of the section line between Sec.36, R2E, T15S, and SEc.1, R2E, T16S.

All the thrust faults are assumed to be like the first in relation to direction of movement (ie., east to west). This movement, however, is not related to the large thrusts of the Basin and Range which are from west to east. The mechanism for the faulting is evidently deep seated as indicated by the steepness of the thrust planes. Gilliland (1963) has suggested that the Twelve Mile formation (Arapien) of the Sanpete-Sevier Valley anticline has forced the beds on the limbs of that fold into a fan shape (ie., overturned on both flanks). It appears that this action also caused shear in the west limb of this anticline which resulted in the imbricant thrusting of overturned Twist Gulch and Morrison formations. One thrust plate, however, contains Twist Gulch which is right side up and appears anamolous with the thrusting of the west limb of an anticline. In fact, it is probably the result of the thrusting of the east limb of a small anticline which formed on the west limb of the major anticline. This idea is reinforced by observations that the Sanpete-Sevier Valley anticline is not smoothly folded but has minor anticlines and synclines imposed on it (Gilliland, 1963).

The very intricate relationship of the thrust faulting can be observed on the north walls of the canyons in the SW 1/4, Sec.36, R2E, T15S.

Before describing the other faulting in the area it is appropriate to mention the phenomena which were used to locate the thrust planes. As alluded to above the examination of sedimentary structures, especially cross bedding, to determine the tops of beds was used extensively. By this process reversals in bed orientation could be located with the obvious implication of a fault between the points of reversal. Ordinarily the crossbedding and outcrops were sufficiently present to determine the location of a fault plane to within 20 feet. However, certain locations such as the tops of hills and dissected pediment surfaces yield no such information and must, therefore, remain in doubt although the writer believes the assumptions represented by the mapping are in line with the observed structural evidence.

In the process of following the reversals the members of the party discovered a most useful fact. The fault planes were often clearly marked by a characteristic purple fault gouge. This criteria had to be carefully used, however, because of the similar appearance of some weathered conglomerates. This purple gouge became most helpful in areas where weathering had covered the slopes or where no suitable crossbedding could be found. Even with this added fact the tracing of the faults in the N 1/2, SW 1/4, Sec.36, R2E, T15S was nearly impossible because the top of the hill was covered by weathering debris from a purple conglomerate of the Morrison (?) formation. Elsewhere in the area, the presence of the purple, calcareous fault gouge was indicative of a fault plane and sometimes led to the discovery of more conclusive proof such as measurable difference in dip across a fault plane.

The thrust faults have been involved in further faulting. In the small canyon referred to above the thrust plate of Morrison (?) formation has been broken by a right lateral tear fault. Only this one thrust plate is involved and the tear fault is probably genetically related to the original thrust. The sense of movement on the fault can be observed in the field as the right lateral separation of the minor fold previously described.

The same thrust sheet has been further involved in faulting in North Coal Canyon. On the north wall of the canyon the beds of the Morrison (?) formation are faulted against one another along a high angle normal fault. The location of the fault is indicated by differences in strike and dip across the fault and by slight differences in lithology. This fault is not related to the thrusting and probably occurred at the same time as the major normal fault along the base of the Gunnison Plateau.

The sharp east front of the Gunnison Plateau immediately makes one think of a fault scarp. In addition small foothills such as those at the mouth of North Coal Canyon have fronts which are squared off and do not taper out to a point. Additionally, dissected pediment surfaces are found raised hundreds of feet above the valley floor. Other evidence of a fault is found in adjacent areas. At the mouth of Wales Canyon a recent alluvial fan has a truncated appearance. In the area to the south, near Point of the Mountain, an outcrop of Flagstaff limestone is found several hundred yards from the base of the mountain in Sanpete Valley. In fact, this fault is the same fault which previous workers have alluded to and which Gilliland (1963) states is responsible for the uplift of the Gunnison Plateau.

Unconformity

An unconformable relationship was seen in only one place in the area studied. Its location is in the SE 1/4, NW 1/2, Sec.36, R2E. T15S and the area exposed is quite small. The erosion of the canyon at this location has cut through the thrust sheets and has exposed the contact between the Red Member of the North Horn formation and the Morrison (?) formation. The contact is clearly an angular unconformity. The Morrison (?) formation is overturned, strikes N20°W, and dips 58°E. The overlying North Horn conglomerate strikes N10°W and dips 20°W. This contact of North Horn conglomerate and Morrison (?) formation is part of the regional unconformity of North Horn and Price River, over Cretaceous and Jurassic formations that other workers have previously described (Spieker 1946, 1949; Hunt, 1956; Gilliland, 1963).

GEOMORPHOLOGY

The geomorphology of the area is controlled by the structural geology and by the stratigraphy. The combined effects of these geologic factors along with the climate has produced a region of varied features. The most prominent of these include a retreating fault scarp, landslides, Toreva blocks, dissected pediments and alluvial fans, small tributary valleys developed on thrust contacts and non-resistant beds, dip slopes on Flagstaff limestone and North Horn formation beds, and headward erosion of canyons nearly perpendicular to the front of the Gunnison Plateau.

The fault scarp produced by the normal fault along the east front of the Gunnison Plateau is migrating westward due to a combination of release fractures, undermining of more resistant beds, and landslides. This removal of material is most active near the rim of the plateau causing that portion to migrate westward at the greatest rate.

One of the chief mechanisms of retreat is landsliding. More resistant sandstone and limestone of the upper North Horn formation and the Flagstaff limestone are underlain by weaker, more easily eroded mudstone and siltstone. These less resistant beds are weakened by sapping and erosion and result in the collapse of the overlying strata. The resulting landslides are of two types and sizes. The smaller of the two results in a chaotic mixture of rock debris in which original bedding cannot be found. The larger of the two is classified as a Toreva block since the bedding can be traced and apparently it was transported as a large block intact.

Repeated movement along the fault has raised the west side up several times during Quaternary time as three distinct pediment levels were mapped. On the tops of several flat top hills accumulations of North Horn and Flagstaff rubble exceed 20 feet in thickness. The base of these deposits is distinct and dips gently east. However, they are now only remnants of previous pediments as erosion of the canyons has cut down to the present pediment surface. In a similar manner an ancient alluvial fan at the mouth of North Coal Canyon has been uplifted approximately 40 feet and subsequently dissected.

The development of the small tributaries to the main canyons show a tendency to follow the strike of the Twist Gulch formation and also the thrust contacts of one plate on another. The relationship to the stratigraphy seems quite sound. The erosion has been most vigorous along relatively soft mudstones in the Twist Gulch. The small tributaries do traverse the strikes of these beds but this can be attributed to the physics of hydrologic flow. The coincidence of thrust plate contacts and stream tributaries may be somewhat more tenuous. These surfaces are, however, planes of weakness and it seems a logical place for erosion to be most active.

Another very prominent feature is the development of dip slopes. On the top of the Gunnison Plateau the Flagstaff limestone dips gently west. Some of the upper Flagstaff units have resisted erosion and produced smooth westward dipping slopes as the more readily eroded Green River and Colton formations were stripped away. A more interesting example of the same phenomenon occurs on the east front of the Gunnison Plateau in the North Horn formation. The Pete's Canyon Member of the North Horn formation has a thick limestone at the base and is overlain by hundreds of feet of mudstone which apparently is easily eroded. As the fault scarp has retreated these mudstones were eroded but the more resistant limestone and the underlying sequence of coal, shale and sandstone have not been as easily removed. As a result, these beds stand out as prominent foothills along the larger mountain front. These hills rise 400 - 600 feet above the main slope and lie along the strike of the beds involved. An excellent example of one such hill lies in the S 1/2, SE 1/4, Sec.26, R2E, T15S. Two or three similar hills of the same type are located along a nearly north trending line.

Finally, the erosion of all the major canyons is proceeding in the same manner. The canyons are deeply incised at their mouths but they extend back perpendicular to Sanpete Valley and rise to the top of the plateau in a distance varying from two to four miles. The headward erosion of North

Coal Canyon has produced a large cove in the mountain front which is impressively rimmed by the lower cliff forming limestone of the Flagstaff limestone.

ECONOMIC GEOLOGY

The mineral deposits in the area covered in this report are few. While there are no metallic deposits of commercial value there are two recoverable non-metallic deposits.

In the middle of the North Horn formation there is a single seam of coal which has been mined to a small degree. There is a mine in North Coal Canyon and another in Pete's Canyon. Neither of these mines is being operated at the present time and it is doubtful that either one ever produced much coal. The total volume of coal in the seam is not great enough to warrant mining of a serious nature in the future.

The accumulation of sand and gravel in the alluvial fans at the mouth of North Coal Canyon and Pete's Canyon are large enough to be of commercial value. The open pits of past operations are ready testimony to the availability of the deposits. In recent years and at the present a quarrying operation at the mouth of Pete's Canyon is producing gravel for construction and maintenance of Utah highways. At the present rate of production the deposit will last for many years.

The presence of a large anticline such as the one that underlies Sanpete and Sevier Valleys immediately brings the possibility of discovering petroleum to mind. The anticline contains a favorable sandstone reservoir at depth in the Nugget or Navajo sandstone. The anticline has not been sufficiently explored as yet so no sound conclusion of its worth can be stated. The only two test wells that have been drilled have been on the east side of the crest of the anticline and have not encountered petroleum. In the vicinity of Wales, however, the anticline is cut by the Gunnison fault with the west side upthrown. It is also known that prior to Jurassic time the greatest accumulation of sediments was in the geosyncline of the Great Basin area. This same area which contains the most sediments will then contain the most potential source beds. If the petroleum has not been lost due to deformation, then one would expect it to migrate out of the geosynclinal basin toward the east and the Sanpete-Sevier Valley anticline. If the fault had occurred before petroleum arrived in the anticline, then the limb west of the fault would be the most logical location to test.

In addition to this the anticline is thought to make an abrupt change in strike at Point of the Mountain. It is pure speculation, but this change in strike may reflect a change at depth that would impede the migration of petroleum up the north plunging anticline. The complex orogenic history of the area, however, makes all such hypotheses very tenuous. Further exploration in the area is in order if the full potential of the region is to be discerned.

GEOLOGIC HISTORY

During the Paleozoic era a geosyncline was located to the west of present day Sanpete Valley and central Utah was a shallow shelf area. In the Jurassic the area of thickest accumulations shifted to central and eastern Utah (Armstrong, 1968) and the Arapien shale (formerly the Twelve Mile Canyon member of the Arapien) was laid down. By the time the Arapien was being deposited the sea was regressing and leaving trapped pockets of saline water which formed the evaporites found today. The climate was probably hot and dry similar to the arid climate of present nearby areas.

The conditions of deposition changed and the Twist Gulch formation was deposited either in the littoral zone or on the coastal flood plain. The source area of the Twist Gulch now supplied the iron necessary for the red pigment. This iron could have been supplied in one of three ways or in a combination of them. Finely divided hematite may have been derived from a soil produced over ferrous rocks in a warm, humid climate; a previously existing red bed may have been eroded; or iron may have been transported in ionic solution and precipitated at the site of deposition in a strongly oxidizing environment. It is certain that the conditions of deposition were somewhat oxidizing to prevent the reduction of the iron in hematite. The climate was probably still hot and dry as during deposition of the previous formation.

The next formation deposited, the Morrison (?) formation, reflects a change in environment of deposition and a definite change in the source area. The sediments become more coarse and resemble the deposits of the piedmont facies. As stated earlier the Morrison (?) formation of the east Gunnison front is probably the same as the Indianola undifferentiated. At any rate, their origin is the same. The change in sedimentation reflects an uplifted source area to the west since the constituents of the conglomerates become coarser in that direction.

Early studies of the Indianola group of the Wasatch Plateau and Indianola undifferentiated of the Gunnison Plateau led Spieker to the same conclusion (Spieker, 1946). In fact recent work has shown that there was a nearby orogenic belt to the west. In the Canyon Range and other areas, eocambrian and Lower Cambrian rocks of the same lithology as the conglomerate pebbles considered here have been thrust into uplifted positions (Armstrong, 1968). In the area considered the late Jurassic to early Cretaceous sedimentation was consistently that of the piedmont. To the east, Cretaceous rocks indicate a series of pulses rather than one strong pulse (Spieker, 1946, 1949).

The Morrison (?) formation is in angular unconformity with the overlying North Horn formation (i. e. the conglomerate of the Red Member of the North Horn formation which is equal to the Price River conglomerate of central Utah). After deposition of the Indianola group, which is conformable with the Morrison (?), the rocks of this area were strongly folded and then eroded. This period of folding has been correlated with the Laramide orogeny and is considered one of the earliest pulses of that activity (Spieker, 1946).

As erosion of the area proceeded, the highland migrated west and this locality once again became the site of piedmont deposition. As a result the basal conglomerate of the North Horn formation (Price River) was deposited. The Red Member of the North Horn is characterized by lithologies similar to the underlying Jurassic formations (see stratigraphy) and it is proposed that these sediments were derived (in part) from a local source to the south where the folded Jurassic rocks had not yet been submerged. This assumption is in line with the work of Spieker (1946, 1949) and subsequent workers who described an overlap of Flagstaff limestone onto folded Twist Gulch and Morrison (?) formations in southern Sanpete and Sevier Valleys. The major source supplied quartzite and limestone pebbles and lay to the west.

This source area was the present day Canyon Range Mountains and vicinity where Armstrong (1968) has demonstrated thrusting in the early Laramide as well as earlier. Although evidence is incomplete in the area studied, other workers have shown conclusively that the orogenic activity of central Utah was not limited to two widely separated events, but occurred as irregular pulses from the Cretaceous through the Laramide (Spieker, 1946; Armstrong, 1968; Hunt, 1956).

The beds of the North Horn formation record a progressive change from deposits formed on a piedmont to deposits laid down on a coastal plain as the western uplands were eroded and migrated west. Flood plain conditions prevailed during deposition of the last two thirds of the North Horn. None-the-less variations in sedimentation are recorded as the coastal plain contained wandering streams and migrating lakes which produced a succession of fluvatile, swamp, and lacustrine deposits. Sedimentation of the North Horn formation continued without interruption noticeable in the stratigraphy throughout the late Cretaceous and into the early Paleocene (Spieker, 1946).

Sometime after the deposition of the North Horn formation, thrust faulting occurred along what is now the east Gunnison front. This faulting is post-folding of the Indianola group as indicated by the structural attitude. It is not clear whether the thrusting occurred shortly after deposition of the basal North Horn which is overlain by Jurassic thrust plates, or whether the faulting has occurred much more recently after consolidation of the North Horn. The force which caused the faulting apparently is directly related to folding of the Sanpete-Sevier Valley anticline. Some geologic features of the region indicate that the fold has been active throughout a long period of time and that the resulting configuration is fanshaped (Armstrong, 1968). Therefore, the mechanical force required to thrust the rocks was potentially present during and between both times considered and the final interpretation must remain open to discussion.

There is evidence which supports the idea of deformation after North Horn consolidation in this particular area. Where thrusting has occurred the overridden beds of the North Horn formation are deformed in a manner characteristic of a brittle material. However, in adjacent areas, especially at Wales Canyon, the basal conglomerates of the North Horn appear to have been pliable during deformation. The answer may be that, as is often the case in geology, neither extreme in itself can explain the phenomena but a synthesis of the two can. The folding may have taken place prior to consolidation of the North Horn gravels during an active period of the anticline. At a later time rejuvenation of the anticline may have produced enough force in some areas to cause thrusting over the now brittle conglomerate and sandstone.

Although all the thrust faults are probably nearly the same age a relative age relationship can be worked out. The oldest fault is the western most one since it is truncated by the next fault east and overridden by it. Similarly the faults are younger towards the east with the youngest fault being nearest Sanpete Valley.

During Paleocene time warping of the area allowed invasion of the Flagstaff lake with the resulting deposition of the Flagstaff limestone. The sediments of the Flagstaff are typical limestone and siltstone which reflect only a period of continued quiescence. Finally, filling of the lake exceeded downwarp and once again fluvial conditions became dominant (Hunt, 1956).

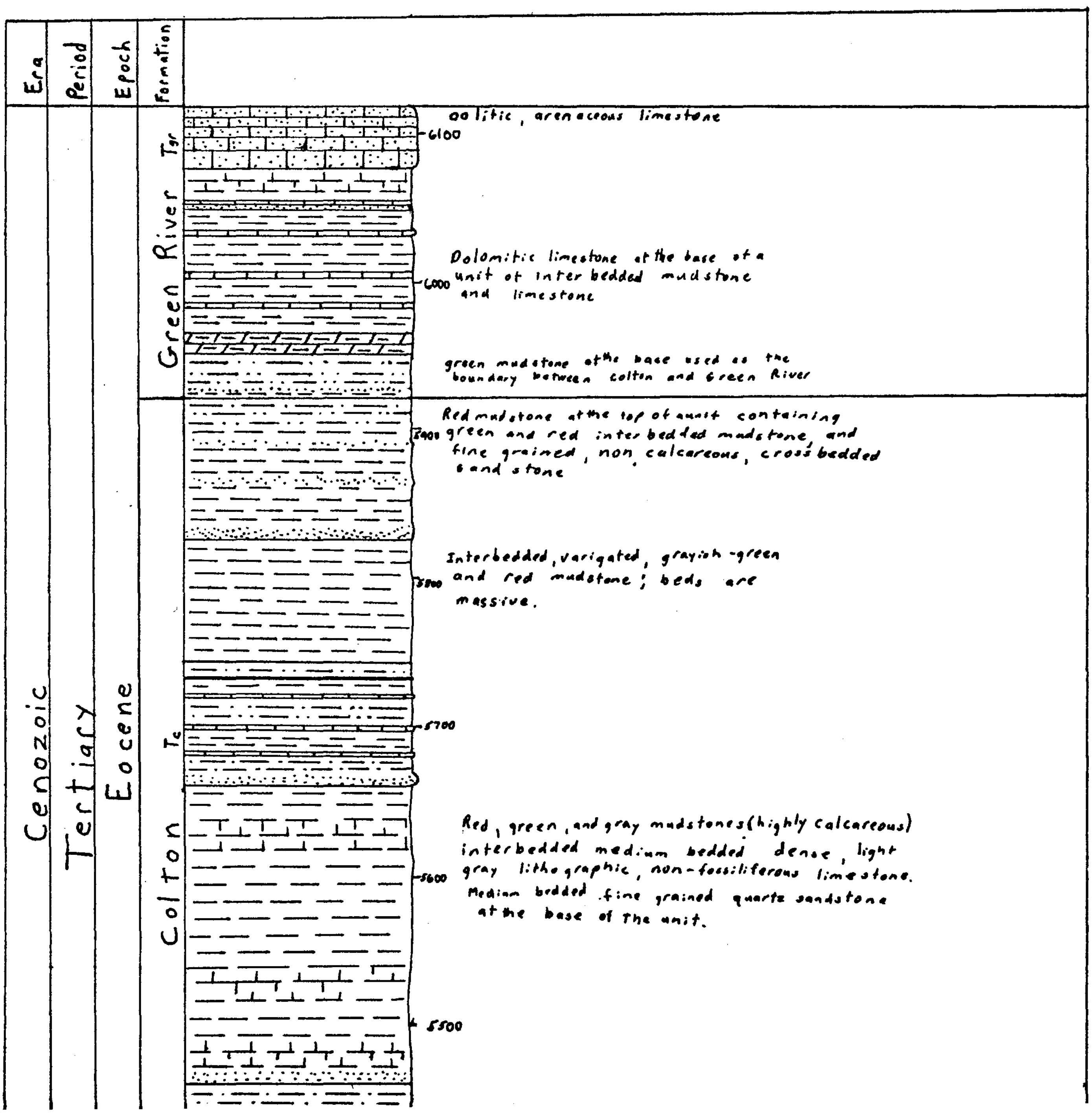
The resulting sedimentation on the flood plain produced the Colton formation which is actually a terrestrial interlude between two lacustrine periods. The surface of deposition was a broad, flat plain which accomodated wandering streams (channel sandstones) and occasional lakes (limestone). The conditions within the sediments probably alternated between reducing and an oxidizing one as the water table fluctuated. This is indicated by the interbedded red and grey-green mudstones.

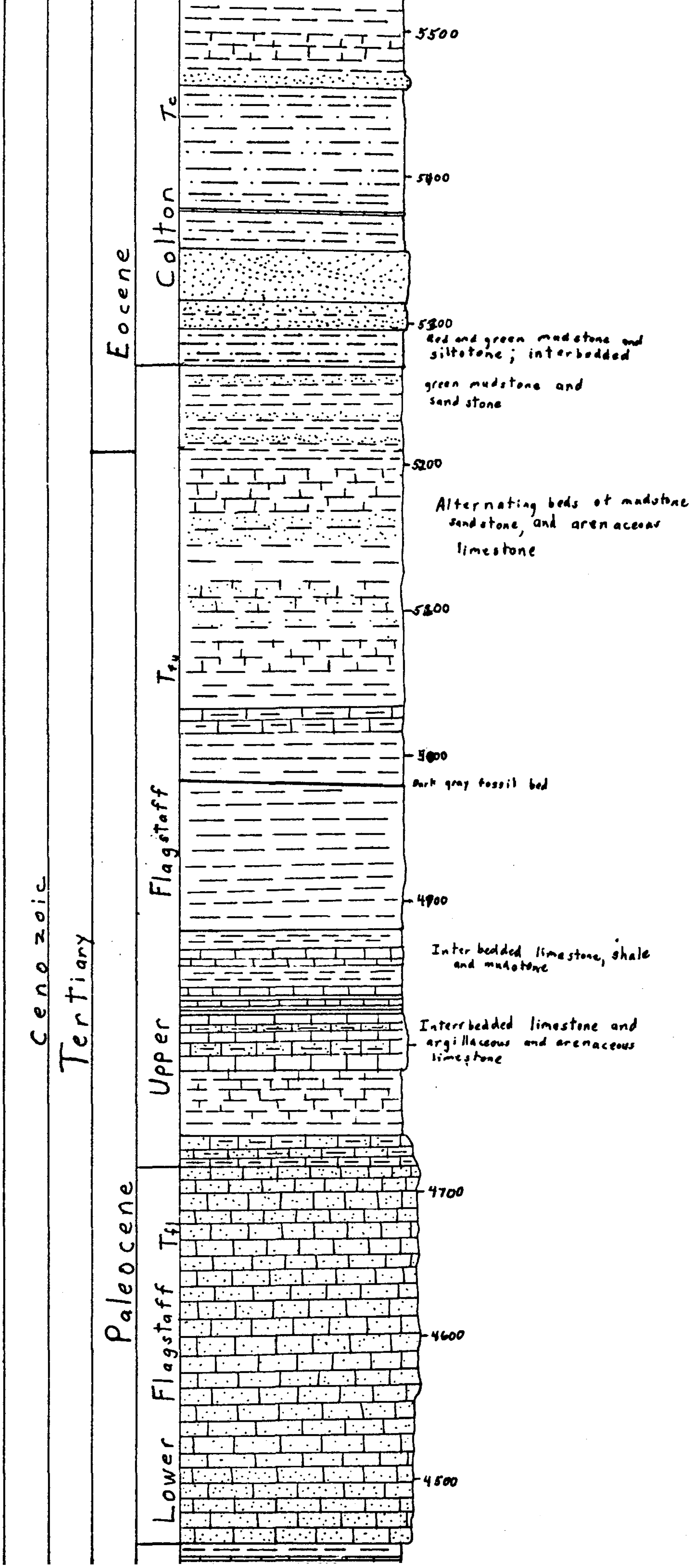
In the early or middle Eocene the area was once again downwarped and a large lake covered the area. This Green River lake was larger than the preceding Flagstaff lake (Hunt, 1956) and the sediments laid down were more clastic than those of the Flagstaff formation. The sedimentation proceeded without disturbance as the downwarp continued.

Sometime after Green River time a large, high angle normal fault occurred just east of the present day Gunnison front. This fault has raised the Gunnison Plateau into its present position and may have a throw of as much as 8,000 feet (Gilliland, 1963). Another much smaller, high angle normal fault in North Coal Canyon probably developed at this time in association with the main fault. This is difficult to discern since the small fault only cuts Morrison (?) strata.

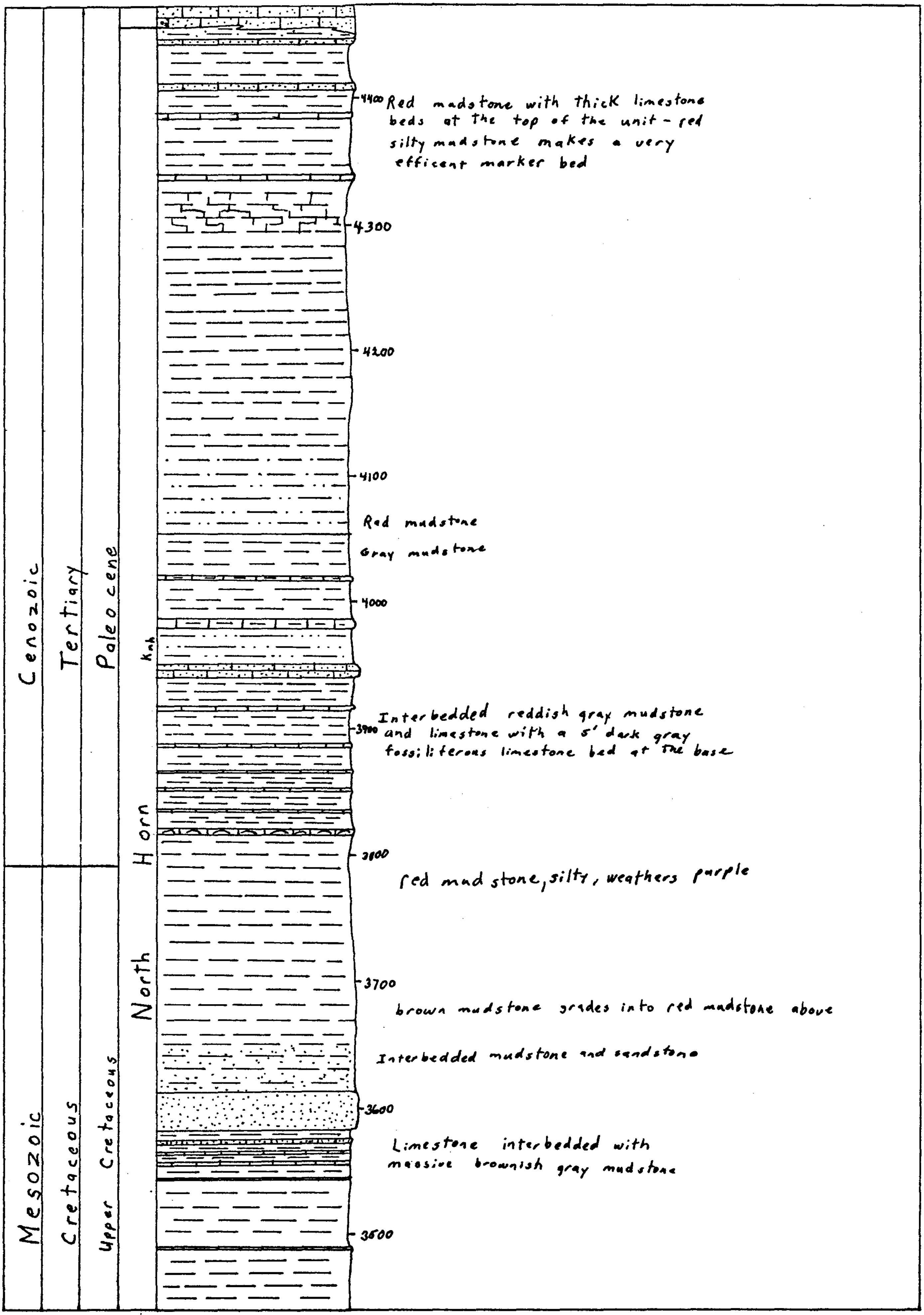
Subsequent minor movement on the major normal fault, weathering, and modern erosion have combined to produce the geomorphic features described above (see Geomorphology).

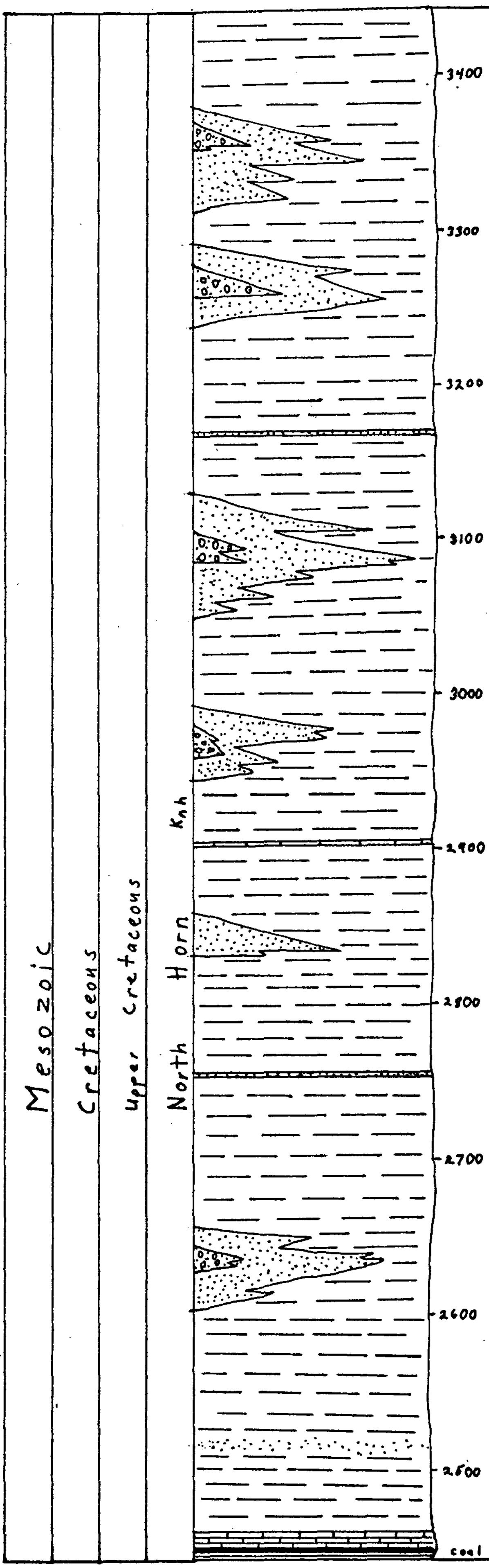
Columnar Section of Beds Exposed
In T 15 S, R 2 E sec. 33-36 and
T 16 S, R 2 E sec. 1-4
Wales Quadrangle
by
Dale Lewis



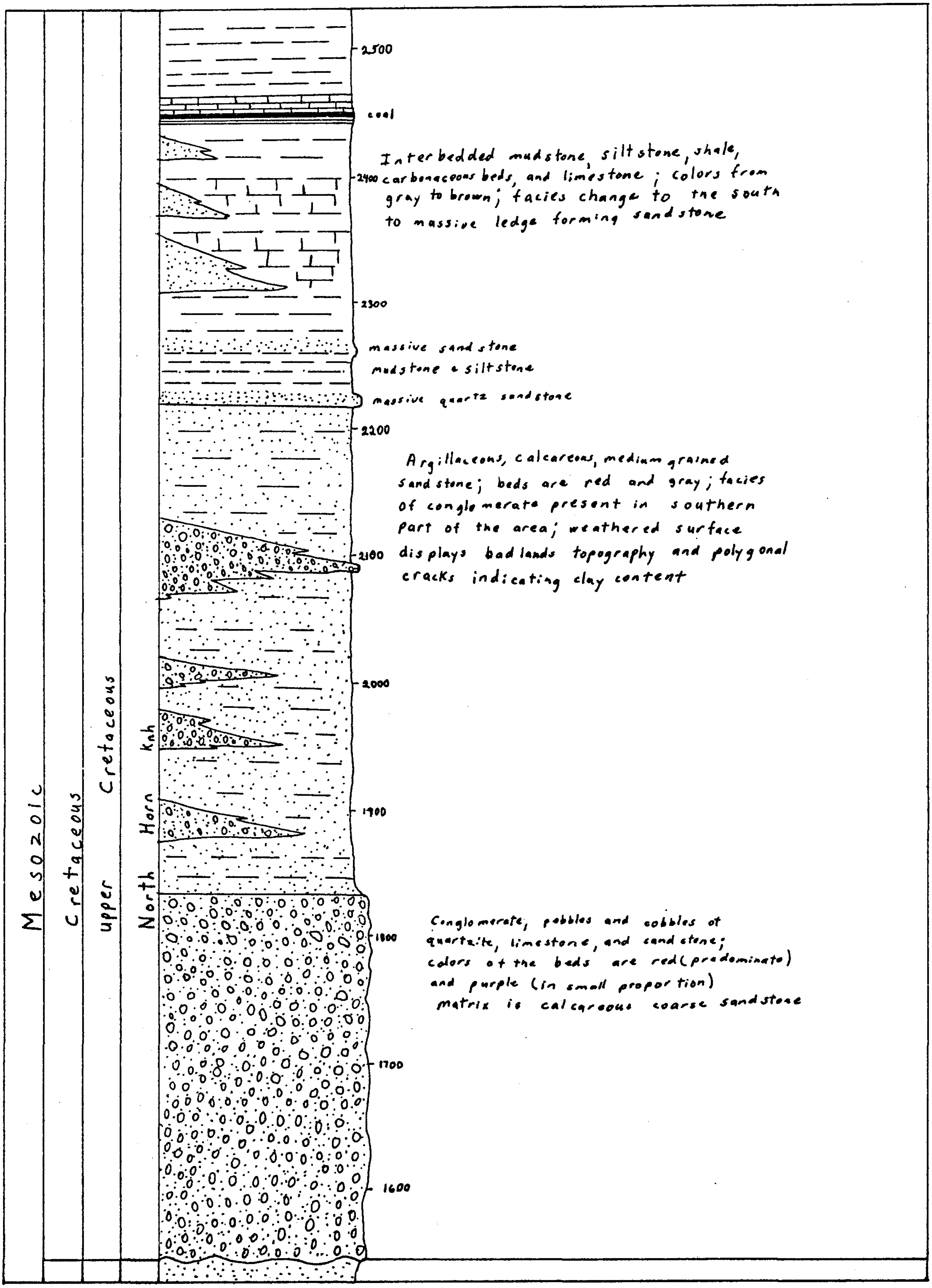


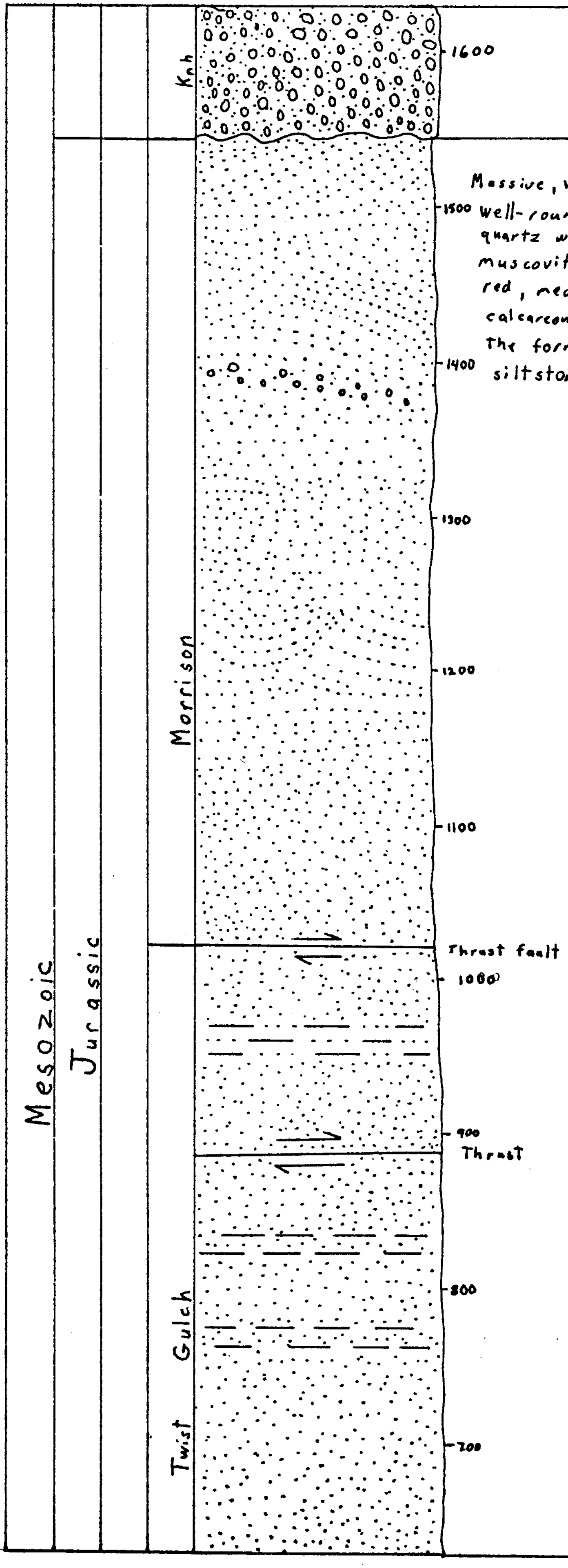
Cenozoic
Tertiary
Eocene
Paleocene
Colton
Tc
Flagstaff
Tfu
Upper
Lower Flagstaff
Tfl
5500
5400
5300
Red and green mudstone and siltstone; interbedded
green mudstone and sand stone
5200
Alternating beds of mudstone sandstone, and arenaceous limestone
5100
5000
Dark gray fossil bed
4900
Inter bedded limestone, shale and mudstone
Interrbedded limestone and argillaceous and arenaceous limestone
4700
4600
4500


Cenozoic
Tertiary
Paleocene
Mesozoic
Cretaceous
Upper Cretaceous
North Horn
Knh
4400
Red mudstone with thick limestone beds at the top of the unit - red silty mudstone makes a very efficent marker bed
4300
4200
4100
Red mudstone
Gray mudstone
4000
3900
Interbedded reddish gray mudstone and limestone with a 5' dark gray fossiliferous limestone bed at the base
3800
red mud stone, silty, weathers purple
3700
brown mudstone grades into red mudstone above
Interbedded mudstone and sandstone
3600
Limestone interbedded with massive brownish gray mudstone
3500

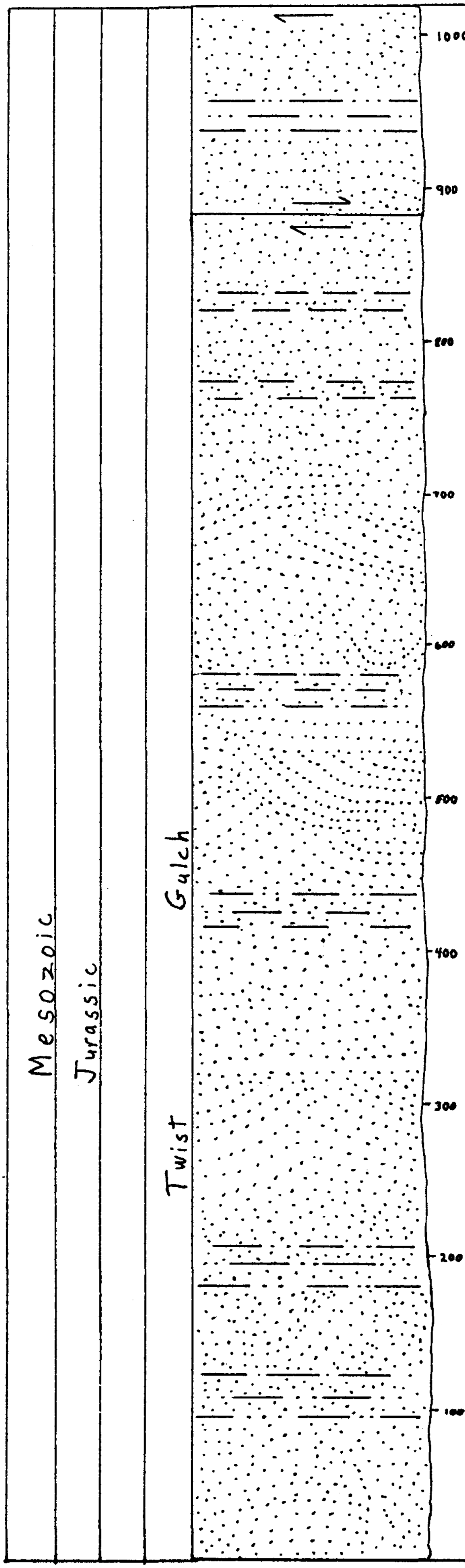


Interbedded mudstone and siltstone (brown, red, purple, gray) with beds of limestone and sandstone
Equivalent facies to the south are massive sandstone with some siltstone and farther south they become conglomeratic


Mesozoic
Cretaceous
upper Cretaceous
North Horn Knh
2500
coal
Interbedded mudstone, siltstone, shale, carbonaceous beds, and limestone; colors from gray to brown; facies change to the south to massive ledge forming sandstone
2400
2300
massive sandstone
mudstone & siltstone
massive quartz sandstone
2200
Argillaceous, calcareous, medium grained sandstone; beds are red and gray; facies of conglomerate present in southern part of the area; weathered surface displays badlands topography and polygonal cracks indicating clay content
2100
2000
1900
Conglomerate, pebbles and cobbles of quartzite, limestone, and sandstone; colors of the beds are red (predominate) and purple (in small proportion) matrix is calcareous coarse sandstone
1800
1700
1600



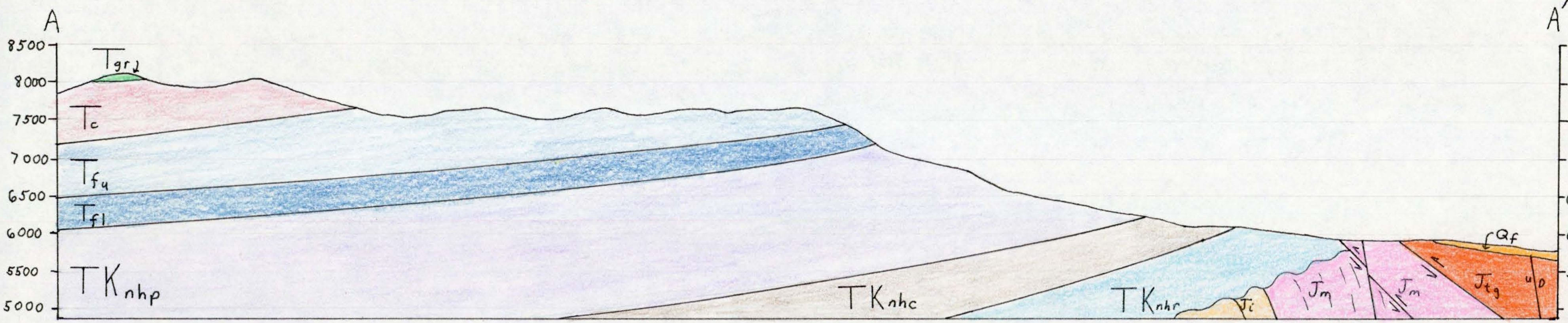
Massive, white, slightly calcareous sandstone, medium, well-rounded grains; minerals predominetely milky quartz with red and yellow quartz, trace amounts of muscovite and biotite.- interbedded with massive red, medium to fine grained quartz sandstone with calcareous and hematite cement - in adjacent areas the formation includes conglomerate and red siltstone



Dark reddish brown to red, slightly calcareous, argillaceous sand stone; grain size from silt to coarse with the average size being fine; high clay content in some beds makes mudstone the dominate lithology (15-20% of the formation is composed of this lithology) crossbedding is weak but can be used to determine tops: red color due to hematite cement and red quartz, rock weathers green in scattered locations on small surfaces

Geologic Cross Sections

1:24000



Quaternary

- Qal — alluvium
- Qf — allivial fan

Tertiary

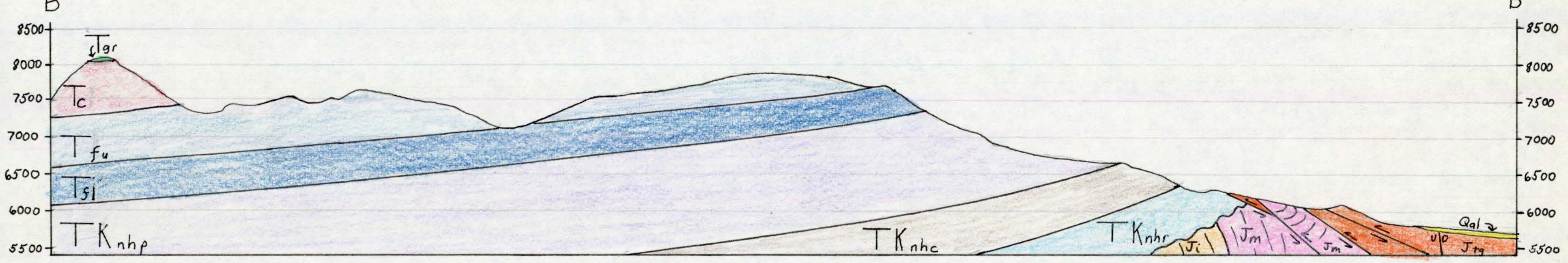
- Tgr — Green River formation
- Tc — Colton formation
- Tfu — Upper Flagstaff member of the Flagstaff limestone
- Tfl — Lower Flagstaff member of the Flagstaff limestone

Tertiary–Cretaceous

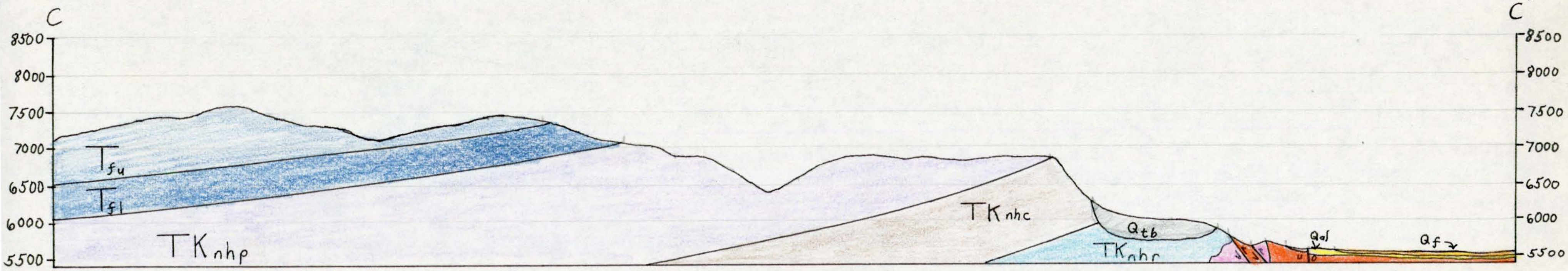
- TKnhp — Pete's Canyon Member: North Horn formation
- TKnhc — N. Coal Canyon Member: North Horn formation
- TKnhr — Red Member: North Horn fm.

Jurassic

- Ji — Indianola Group (possibly Cretaceous)
- Jm — Morrison (?) formation
- Jtg — Twist Gulch formation



B
B′
8500
8000
7500
7000
6500
6000
5500
Tgr
Tc
Tfu
Tfl
TKnhp
TKnhc
TKnhr
Ji
Jm
Jm
Qal
u
o
Jrg



C
C′
8500
8000
7500
7000
6500
6000
5500
Tfu
Tfl
TKnhp
TKnhc
Qtb
TKnhr
Qal
Qf
u
o

References Cited

Armstrong, R. L., 1968, "Sevier Orogenic Belt in Nevada and Utah:" G. S. A. Bull., V. 79, p. 429-458.

Gazin, C. L., 1938, "A Paleocene mammalian fauna from central Utah": Washington Acad. Sci. Jour., v. 29, p. 273-286.

Gilliland, W. N., 1963, "Sanpete-Sevier anticline of central Utah": G. S. A. Bull., V. 74, p. 115-124.

Hardy, C. J., 1952, "Eastern Sevier Valley, Sevier and Sanpete Counties, Utah": Utah Geol. and Min. Surv. Bull., 43, p. 1-98.

Hardy, C. J. and Zeller, H. D., 1953, "Geology of the west-central part of the Gunnison Plateau, Utah": G. S. A. Bull., V. 64, p. 1261-1278.

Hayden, F. V., 1869, U. S. Geol. Surv. Terr. Third Annual Report, p. 89-92.

Hunt, C. B., 1956, "Cenozoic Geology of the Colorado Plateau": U. S. Sur. Prof. Paper 279, 99p.

La Rocque, J. A. A., 1951,"Mulluscan fauna of the Flagstaff formation, central Utah (abs.)": G. S. A. Bull., V. 62, p. 1457-1458.

Spieker, E. M., 1946, "Late Mesozoic and Early Cenozoic History of Centrla Utah": U. S. Geol. Survey, Prof. Paper 205D, pp. 117-160.

Spieker, E. M., 1949, "Sedimentary Facies and Associated Diastrophism in the Upper Cretaceous of Central and Eastern Utah": G.S.A., Mem. 39, p. 55-82.

Spieker, E. M. and Reeside, J. B., Jr., 1925,"Cretaceous and Tertiary Formations of the Wasatch Plateau, Utah": G. S. A. Bull., V. 36, p. 440-462.